2.0 SOURCE ASSESSMENT

Waters of the Christina River Basin are used for recreation, public water supply, and to support aquatic life. Some of these uses are threatened due to impairment caused by point and nonpoint sources of bacteria and sediment. PADEP and DNREC identified the impaired stream segments based on historical monitoring data and biological integrity field surveys. The two state agencies use different bacterial indicators in their respective water quality standards for pathogens. Pennsylvania uses fecal coliform bacteria as an indicator of bacteria contamination whereas, Delaware uses enterococcus bacteria. While both states list waterbodies for bacteria impairments, only Pennsylvania lists waterbodies for sediment, suspended solids, or siltation impairments.

Fecal coliform is a specific kind of coliform bacteria found primarily in the intestinal tracts of mammals and birds. These bacteria are usually released into the environment through human and animal feces. The presence of fecal coliform bacteria pollution may come from storm water runoff, pets, wildlife, and human sewage. If present in high concentrations in recreational waters and are ingested while swimming or enter the skin through a cut or sore, fecal coliform may cause disease, infections, or rashes.

Enterococcus is a common bacterium normally found in the intestinal tract of warm-blooded animals including humans. The presence of enterococci in surface water samples is used as an indicator of the presence of human sewage. Enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to die off in saltwater.

A customized modeling framework was developed to support determination of bacteria and sediment TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model (Hydrolic Systems Program Fortran (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin by the USGS (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a Combined Sewer Overflow (CSO) flow model (XP-SWMM) developed by the City of Wilmington, and (3) a hydrodynamic model developed using the computational framework of the Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1992). Development of inputs for these models involved the analyses of historical water quality and streamflow data to estimate point and nonpoint sources of bacteria and sediment.

2.1 Point Sources

The term “point source” refers to any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container including vessels or other floating craft from which pollutants are or may be discharged. The point source also includes concentrated animal feeding operations, places where animals are confined and fed. Storm water runoff from certain areas may also be considered a point source because the water is transported through a pipe or ditch.

Estimating the transport of sediments and pathogens into a surface waterbody from most point sources is a fairly straightforward matter. Wastewater treatment plants (WWTPs), CSOs, and municipal separate storm sewer systems (MS4s) discharge though a constructed conveyance to a waterbody. Many of the pathogen organisms transported to WWTPs are removed during the treatment process, and permit limits are established to ensure that WWTPs meet water quality standards. However, in some instances failures or leaks may occur, or a wet weather event may create flows that exceed the capacity of the WWTP or CSO. This can lead to a discharge of contaminated water exceeding the permitted limits into the river system. MS4s discharge to waterbodies without being treated by a WWTP.

2.1.1 Wastewater Treatment Plants

Treated industrial and municipal sewage can be a point source of sediment and bacterial contamination. Not all human pathogens or sediment are removed or rendered harmless by treatment processes. Periodic effluent overflows and high-flow bypass in WWTPs can cause occasional high loading of pathogens. Raw sewage entering the WWTP typically has a total coliform count ranging from 10^7 to 10^9 cfu/100 mL (Novotny et al., 1989). Associated with raw sewage are proportionally high concentrations of pathogenic bacteria, viruses and protozoans. A typical wastewater treatment plant reduces the total coliform count by about three orders of magnitude. The magnitude of reduction, however, varies with the treatment process.

Treatment of municipal waste is generally identified as primary, secondary or advanced (also called tertiary) treatment, although the distinctions are somewhat arbitrary. Primary treatment involves removing suspended solids with screens and the use of gravity settling ponds followed by disinfection. Most protozoan cysts settle out in ponds after 11 days due to their size (EPA, 2001). Secondary treatment uses biological treatment to decompose organic matter to cell material and by-products, and the subsequent removal of cell matter, usually by gravity settling. Activated sludge processes involve the production of an activated mass of microorganisms capable of stabilizing waste aerobically. Secondary treatment by activated sludge typically reduces bacteria concentrations by 90 to 99 percent.

Tertiary treatment is any practice beyond secondary treatment and is very effective in destroying most pathogens. Tertiary treatment can include disinfection, filtration, and coagulation. Disinfection is the most common treatment technique to combat waterborne diseases, and the most frequently used disinfectant is chlorine (EPA, 2001). Chlorine kills many microbes, including most pathogens, except protozoan cysts, which are resistant to chlorine. Other disinfectants used are ozone, ultraviolet light, and iodine.

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. The locations of NPDES facilities in the Christina River Basin are shown in Figure 2-1 and listed in Table 2-1. The fecal coliform bacteria, enterococci bacteria, and total suspended solids loads for each of the NPDES facilities, based on permit flow rate, are provided in Table 2-2. Note that fecal coliform bacteria were not simulated for the Delaware or Maryland NPDES facilities.

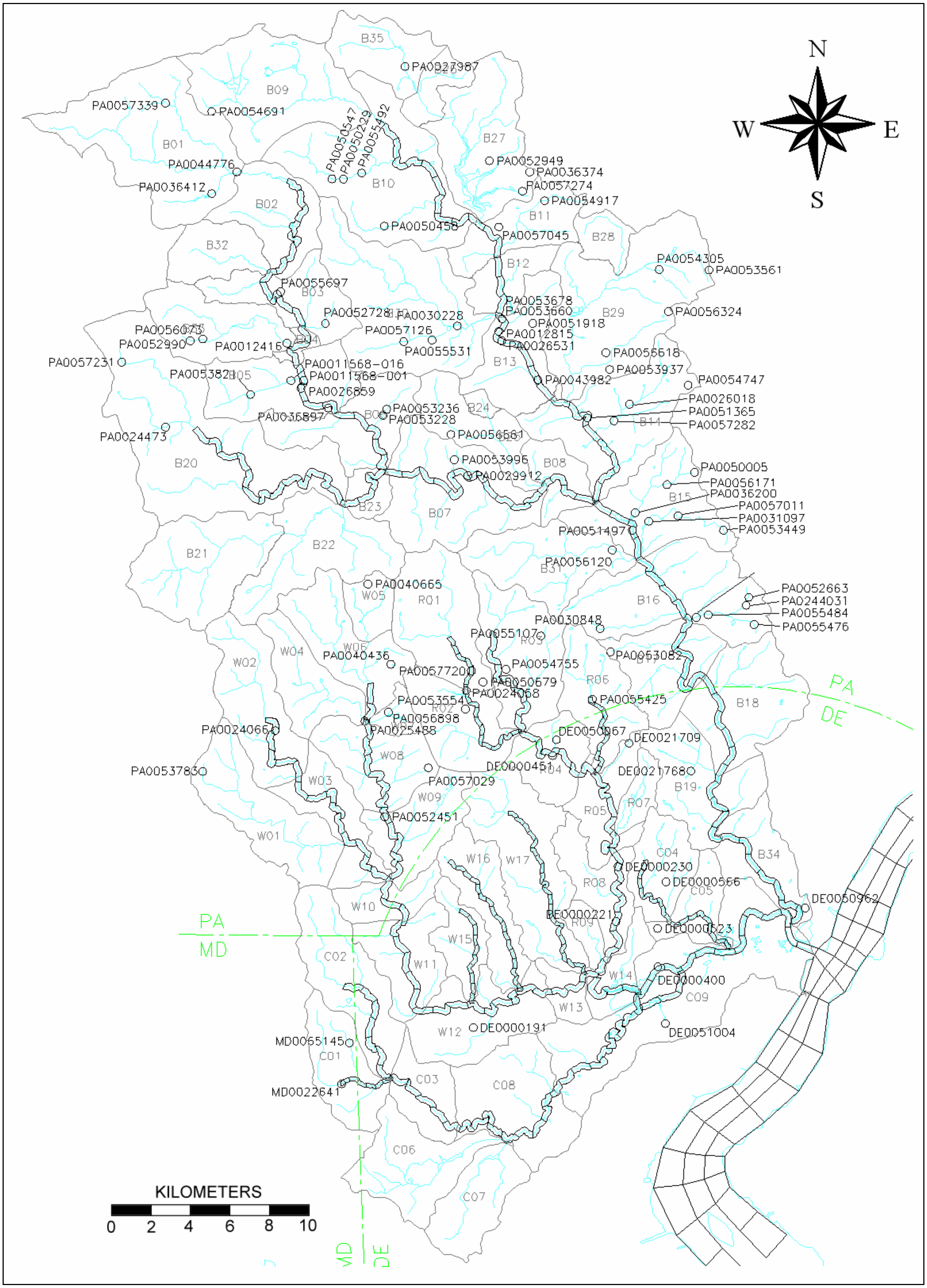

Figure 2-1. NPDES discharges in Christina River Basin

Table 2-1. NPDES point source discharges in Christina River Basin

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek (main stem)								
76.610	54,15	DE0050962	0.0000	SWR	AMTRAK	TB-Brandywine Creek	Industrial	Stormwater
83.554	54,27	DE0021768	0.0250	STP	Winterthur Museum	Clenney Run	Municipal	Small STP
88.644	54,37	PA0053082	0.0206	STP	Mendenhall Inn	TB Brandywine Creek	Commercial	Small STP
89.917	54,38	PA0052663	0.0900	STP	Knight's Bridge Co/Villages at Painters	Harvey Run	Commercial	Small STP
89.917	54,38	PA0055476	0.0400	STP	Birmingham TSA/Ridings at Chadds Ford	TB Harvey Creek	Municipal	Small STP
89.917	54,38	PA0055484	0.0005	SRD	Keating Herbert & Elizabeth	TB Brandywine Creek	Municipal	Single Residence STP
89.917	54,38	PA0244031	0.1500	STP	Chadds Ford Township	Harvey Run		
90.553	54,39	PA0030848	0.0063	STP	Unionville - Chadds Ford Elem. School	Ring Run	Municipal	Small STP
93.098	54,42	PA0056120	0.0005	SRD	Schindler	Pocopson Creek	Municipal	Single Residence STP
92.462	54,43	PA0031097	0.0170	STP	Radley Run C.C.	Radley Run	Municipal	Small STP
92.462	54,43	PA0053449	0.1500	STP	Birmingham Twp. STP	Radley Run	Municipal	Small STP
93.735	54,43	PA0057011	0.0773	STP	Thornbury Twp./Bridlewood Farms STP	Radley Run		
92.462	54,44	PA0036200	0.0320	STP	Radley Run Mews	Plum Run	Municipal	Small STP
94.371	54,44	PA0056171	0.0005	SRD	McGlaughlin Jeffrey	Plum Run	Municipal	Single Residence STP
94.371	54,44	PAG050005	0.1400	GWC	Sun Company	TB Brandywine Creek	GWCleanup	New permit 03/27/98
94.371	54,44	PA0051497	0.0300	NCW	Lenape Forge	Brandywine Creek	Industrial	Cooling Water
Brandywine Creek East Branch								
98.647	54,52	PA0026018	1.8000	MUN	West Chester Borough MUA/Taylor Run	Taylor Run	Municipal	Large STP
98.647	54,52	PA0057282	0.0005	SRD	Jonathan & Susan Pope	TB Valley Creek	Municipal	Single Residence STP
99.276	54,53	PA0051365	0.3690	WFP	PA American Water	EB Brandywine Creek	Municipal	Ingram's Mill-Filter Backwash
100.535	54,55	PA0053937	0.0005	SRD	William and Patricia Kratz	Broad Run Creek	Municipal	Single Residence STP
100.535	54,55	PA0056324	0.0440	GWC	Mobil SS#16-GPB	TB-WB Valley Run	Commercial	DP
100.535	54,55	PA0056618	0.0005	SRD	O'Cornwell David & Jeanette	Broad Run	Municipal	Single Residence STP
100.535	54,55	PA0054305	0.0000	IND	Sun Co, Inc. (R&M)	TB Valley Creek	Industrial	
100.535	54,55	PA0053561	0.0360	GWC	Johnson Matthey	Valley Creek	GWCleanup	Permitted 03/12/96
101.794	54,57	PA0043982	0.4000	ATP2	Broad Run Sew Co.	EB Brandywine Creek	Municipal	Large STP
103.682	54,61	PA0012815	1.0280	IND	Sonoco Products	EB Brandywine Creek	Industrial	Paper Company - Mill Raceway
103.682	54,60	PA0026531	7.5000	ATP2	Downingtown Area Regional Authority	EB Brandywine Creek	Municipal	Large STP
104.312	54,61	PA0051918	0.1440	NCW	Pepperidge Farms	Parke Run Creek	Industrial	Cooling Water
103.682	54,61	PA0055531	0.0007	STP	Khalife Paul	TB Valley Run	Commercial	Small STP
104.312	54,61	PA0057126	0.0000	IND	Hess Oil - SS #38291	Valley Run	Commercial	DP
104.312	54,61	PA0030228	0.0225	STP	Downingtown I&A School	Beaver Creek	Municipal	No flow since Feb 1994
104.312	54,61	PA0053678	0.0000	IND	Lambert Earl R.	EB Brandywine Creek	Industrial	DP
104.312	54,61	PA0053660	0.0000	IND	Mobil Oil Company #016	EB Brandywine Creek	Commercial	Air stripper at Service Sta
106.830	54,65	PA0054917	0.4750	STP	Uwchlan Twp. Municipal Authority	Shamona Creek	Municipal	Eagleview CC STP
107.459	54,66	PA0057045	0.0000	SWR	Shyrock Brothers, Inc.	EB Brandywine Creek	Commercial	Stormwater
108.088	54,67	PA0027987	0.0500	STP	Pennsylvania Tpk./Caruiel Service Plaza	Marsh Creek	Commercial	Small STP
108.088	54,67	PA0036374	0.0150	STP	Eaglepoint Dev. Assoc.	TB Marsh Creek	Municipal	Small STP
108.088	54,67	PA0052949	0.0000	IND	Phila. Suburban Water Co.	Marsh Creek	Industrial	Uwchlan DP
108.088	54,67	PA0057274	0.0005	SRD	Michael & Antionette Hughes	TB Marsh Creek	Municipal	Single Residence STP
109.977	54,70	PA0050458	0.0531	STP	Little Washington Drainage Co.	Culbertson Run	Municipal	Small STP
112.495	54,74	PA0057827	0.0005	SRD	McKenna	Indian Run	Municipal	Single Residence STP
112.495	54,74	PA0050547	0.0375	STP	Indian Run Village MHP	Indian Run	Municipal	Small STP
112.495	54,74	PA0055492	0.0005	SRD	Andrew and Gail Woods	Indian Run	Municipal	Single Residence STP
113.753	54,76	PA0054691	0.0005	SRD	Stoltzfus Ben Z.	TB Brandywine Creek	Municipal	Single Residence STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek West Branch								
97.976	46,79	PA0056561	0.0000	SWR	Richard M. Armstrong Co.	Broad Run	Commercial	Stormwater
101.708	40,79	PA0029912	0.1000	STP	Embreeville Hospital	WB Brandywine Creek	Municipal	Large STP
102.330	39,79	PA0053996	0.0005	SRD	Redmond Michael	TB-WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053228	0.0005	SRD	Gramm Jeffery	WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053236	0.0005	SRD	Woodward Raymond Sr. STP	WB Brandywine Creek	Municipal	Single Residence STP
110.416	24,79	PA0036897	0.3900	ATP1	South Coatesville Borough	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0026859	3.8500	ATP1	Coatesville City Authority	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0011568-001	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0011568-016	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0053821	0.0000	SWR	Chester County Aviation Inc.	Sucker Run	Commercial	Stormwater
112.282	20,79	PA0012416	0.1400	WFP	PA American Water	Rock Run	Industrial	Water Filtration Plant-Backwash
112.282	20,79	PA0052990	0.0005	SRD	Mitchell Rodney	Rock Run	Municipal	Single Residence STP
112.282	20,79	PA0056073	0.0005	SRD	Vreeland Russell Dr.	TB Rock Run	Municipal	Single Residence STP
113.526	18,79	PA0052728	0.0004	STP	Farmland Industries Inc./Turkey Hill	WB Brandywine Creek	Industrial	Small STP
114.770	16,79	PA0055697	0.0490	STP	Spring Run Estates	WB Brandywine Creek	Commercial	Small STP
120.368	06,79	PA0036412	0.0550	STP	Tel Hai Retirement Community	TB-WB Brandywine Creek	Municipal	Small STP
120.368	06,79	PA0044776	0.6000	STP	NW Chester Co. Municipal Authority	WB Brandywine Creek	Municipal	Large STP
120.368	06,79	PA0057339	0.0005	SRD	Brian & Cheryl Davidson	TB-WB Brandywine Creek	Municipal	Single Residence STP
Buck Run								
117.041	33,61	PA0024473	0.7000	STP	Parkersburg Borough Authority WWTP	TB-Buck Run	Municipal	Small STP-discontinued 06/10/97
117.041	33,61	PA0057231	0.0005	SRD	Archie & Cloria Shearer	TB-Buck Run	Municipal	Single Residence STP
Christina River (tidal)								
82.274	45,13	DE0000400-001	0.0000	NCW	Ciba-Geigy Corp.	Christina River	Industrial	Cooling Water
83.561	43,09	DE0051004	0.0000	SWR	Boeing	Nonesuch Creek	Industrial	Stormwater
Christina River West Branch								
99.587	16,09	MD0065145	0.0500	STP	Highlands WWTP	WB Christina River	Municipal	Small STP
100.209	14,09	MD0022641	0.4500	STP	Meadowview Utilities, Inc.	WB Christina River	Municipal	Small STP
Red Clay Creek								
89.828	43,26	DE0000221-001	0.0060	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
89.828	43,26	DE0000221-003	0.0040	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
91.746	43,29	DE0000230-001	0.3500	NCW	Hercules Inc.	Red Clay Creek	Industrial	Cooling Water
95.583	43,35	DE0021709-001	0.0150	STP	Greenville Country Club	TB-Red Clay Creek	Municipal	Small STP
96.861	43,37	PA0055425	0.0005	SRD	D'Ambro Anthony Jr.-Lot #22	TB-EB Red Clay Creek	Municipal	Single Residence STP
98.780	43,40	DE0050067	0.0015	STP	Center for Creative Arts	TB-Red Clay Creek	Municipal	Small STP
98.780	43,40	DE0000451-002	2.1700	NCW	NVF Yorklyn	Red Clay Creek	Industrial	Stormwater/Cooling Water
101.337	43,44	PA0055107	0.1500	STP	East Marlborough Township STP	TB-EB Red Clay Creek	Municipal	Large STP
Red Clay Creek West Branch								
103.313	32,43	PA0053554	0.0000	SWR	Earthgro Inc.	WB Red Clay Creek	Industrial	Stormwater
103.950	30,43	PA0024058	1.1000	STP	Kennett Square Boro. WWTP	WB Red Clay Creek	Municipal	Large STP
104.268	29,43	PA0050679	0.2500	NCW	National Vulcanized Fiber (NVF)	TB-WB Red Clay Creek	Industrial	Cooling Water
104.579	28,43	PA0057720-001	0.0720	STP	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Process Water
104.579	28,43	PA0057720-002	0.0900	NCW	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Cooling Water
White Clay Creek								
93.090	32,18	DE0000191-001	0.0300	NCW	FMC Corp.	Cool Run	Industrial	Stormwater/Cooling Water
102.824	15,18	PA0053783	0.0200	STP	Avon Grove School Dist	TB-WB White Clay Creek	Commercial	Small STP
108.696	06,18	PA0024066	0.2500	STP	West Grove Borough Authority STP	MB White Clay Creek	Municipal	Large STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
White Clay Creek East Branch								
102.750	19,24	PA0052451	0.0012	STP	Frances L. Hamilton Oates STP	EB White Clay Creek	Municipal	Small STP
104.020	19,26	PA0057029	0.1440	GWC	Hewlett Packard Co.	Egypt Run	GWCleanup	Groundwater Cleanup
106.560	19,30	PA0025488	0.3000	ATP2	Avondale Borough Sewer Authority	Indian Run	Municipal	Large STP
106.560	19,30	PA0056898	0.0650	IND	To-Jo Mushrooms Inc.	Trout Run	Industrial	Small STP-online Jan 98
107.830	19,32	PA0040436	0.0090	STP	Chadds Ford Investment Co./Red Fox GC	TB-EB White Clay Creek	Municipal	Small STP
107.830	19,32	PA0040665	0.0100	STP	Stone Barn Restuarantand Apt. Cplx	EB White Clay Creek	Commercial	Small STP
Little Mill Creek								
82.441	41,55	DE0000523-001	0.0000	SWR	General Motors Assembly	Little Mill Creek	Industrial	Stormwater
83.373	38,55	DE0000566	0.0000	SWR	DuPont Chestnut Run	Little Mill Creek	Industrial	Stormwater/Cooling Water
Delaware River								
63.839	57,04	DE0021555-001	0.5500	MUN	Delaware City STP	Delaware River	Municipal	
65.272	57,05	DE0000256-601	13.0000	IND	Star Enterprises	Delaware River	Industrial	
65.272	57,05	DE0000612-001	0.8000	IND	Formosa Plastics Corp.	Delaware River	Industrial	
65.272	57,05	DE0020001-001	0.6800	MUN	Standard Chlorine	Delaware River	Municipal	
65.272	57,05	DE0050911-001	0.3000	MUN	Occidental Chemical Corp.	Delaware River	Municipal	
75.237	57,15	DE0020320-001	90.0000	MUN	City of Wilmington	Delaware River	Municipal	
77.162	57,17	DE0000051-001	5.2000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-002	3.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-003	6.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
81.307	57,20	DE0000655-001	33.3000	IND	General Chemical Corporation	Delaware River	Industrial	
83.907	57,22	PA0012637-002	52.3500	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-101	69.8000	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-201	3.3400	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
85.199	57,23	PA0027103-001	44.0000	MUN	Delcora	Delaware River	Municipal	
82.639	58,21	NJ0005045-001	0.5000	IND	Monsanto	Delaware River	Industrial	SEE NOTE 2
63.839	59,04	NJ0024856-001	1.4450	MUN	City of Salem	Delaware River	Municipal	SEE NOTE 1
69.534	59,09	NJ0021598-001	2.4650	MUN	Pennsville Sewage Authority	Delaware River	Municipal	SEE NOTE 1
73.339	59,12	NJ0005100-661	22.9000	IND	Dupont-Chambers Works	Delaware River	Industrial	SEE NOTE 1
75.237	59,15	NJ0021601-001	1.7290	MUN	Carneys Pt. Sewage Authority	Delaware River	Municipal	SEE NOTE 1
76.045	59,16	NJ0024023-001	0.9500	MUN	Penns Grove Sewage Authority	Delaware River	Municipal	SEE NOTE 1
77.162	59,17	NJ0024635-001	0.0366	MUN	Fort Dix/Pedricktown Facility	Delaware River	Municipal	SEE NOTE 1
79.919	59,19	NJ0004286-001	2.1000	IND	Geon	Delaware River	Industrial	
82.639	59,21	NJ0027545-001	0.9860	MUN	Logan Township MUA	Delaware River	Municipal	SEE NOTE 1

NOTES:
[1] No flow limit available in PCS data base; flow limit shown is maximum reported flow during 01/01/95 to 12/31/98
[2] No flow limit or reported flow available in PCS data base; flow limit shown is an estimate

Table 2-2. Fecal coliform, *enterococci*, and TSS loads for NPDES facilities

NPDES Number	HSPF Subbasin	Flow (mgd)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	TSS (kg/day)	Fecal Coliform (cfu/day)	Enterococci (cfu/day)
Brandywine Creek main stem								
DE0021768	B19	0.0250	15		100	1.42		9.464E+07
PA0053082	B17	0.0206	10	200	100	0.78	1.560E+08	7.798E+07
PA0052663	B16	0.0900	10	200	100	3.41	6.814E+08	3.407E+08
PA0055476	B16	0.0400	10	200	100	1.51	3.028E+08	1.514E+08
PA0244031	B16	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0055484	B16	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0030848	B16	0.0063	30	200	100	0.72	4.770E+07	2.385E+07
PA0056120	B31	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0031097	B15	0.0170	20	200	100	1.29	1.287E+08	6.435E+07
PA0053449	B15	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0057011	B15	0.0773	30	200	100	8.78	5.852E+08	2.926E+08
PA0036200	B15	0.0320	30	200	100	3.63	2.423E+08	1.211E+08
PAG0050005	B15	0.1400	10	2	2	5.30	1.060E+07	1.060E+07
PA0051497	B15	0.0300	10	2	2	1.14	2.271E+06	2.271E+06
PA0056171	B15	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Brandywine Creek East Branch								
PA0026018	B14	1.5000	30	200	100	170.34	1.136E+10	5.678E+09
PA0057282	B14	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0051365	B14	0.3690	20	2	2	27.94	2.794E+07	2.794E+07
PA0053937	B29	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0056324	B29	0.0440	10	2	2	1.67	3.331E+06	3.331E+06
PA0056618	B29	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053561	B29	0.0360	10	2	2	1.36	2.725E+06	2.725E+06
PA0043982	B13	0.4000	30	200	100	45.42	3.028E+09	1.514E+09
PA0012815	B13	1.0280	50	200	100	194.57	7.783E+09	3.891E+09
PA0026531	B13	7.5000	30	200	100	810.15	5.687E+10	2.839E+10
PA0030228	B30	0.0225	20	200	100	1.70	1.703E+08	8.517E+07
PA0051918	B13	0.1440	10	2	2	5.45	1.090E+07	1.090E+07
PA0055531	B30	0.0007	30	200	100	0.08	5.300E+06	2.650E+06
PA0054917	B11	0.4750	20	200	100	35.96	3.596E+09	1.798E+09
PA0036374	B27	0.0150	30	200	100	1.70	1.136E+08	5.678E+07
PA0057274	B27	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0050458	B10	0.0351	20	200	100	2.66	2.657E+08	1.329E+08
PA0057827	B10	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0050547	B10	0.0375	20	200	100	2.84	2.839E+08	1.420E+08
PA0055492	B10	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0052949	B10	0.0030	20	2	2	0.23	2.271E+05	2.271E+05
PA0027987	B10	0.0050	20	200	100	0.38	3.785E+07	1.893E+07
PA0054691	B09	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Brandywine Creek West Branch								
PA0029912	B07	0.1000	30	200	100	11.36	7.571E+08	3.785E+08
PA0053996	B07	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053228	B06	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053236	B06	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0036897	B05	0.3900	30	200	100	44.29	2.953E+09	1.476E+09
PA0026859	B05	3.8500	30	200	100	437.22	2.915E+10	1.457E+10
PA0011568-001	B05	0.6400	30	200	100	72.68	4.845E+09	2.423E+09
PA0011568-016	B05	0.5045	30	200	100	57.29	3.819E+09	1.910E+09
PA0056073	B33	0.0005	20	200	100	0.04	3.785E+06	1.893E+06

NPDES Number	HSPF Subbasin	Flow (mgd)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	TSS (kg/day)	Fecal Coliform (cfu/day)	Enterococci (cfu/day)
PA0012416	B33	0.1400	20	2	2	10.60	1.060E+07	1.060E+07
PA0052990	B33	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0052728	B03	0.0004	30	200	100	0.05	3.028E+06	1.514E+06
PA0055697	B03	0.0490	30	200	100	5.56	3.710E+08	1.855E+08
PA0036412	B01	0.0550	28	200	100	5.83	4.164E+08	2.082E+08
PA0044776	B01	0.6000	30	200	100	68.14	4.542E+09	2.271E+09
PA0057339	B01	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0057231	B20	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Christina River								
MD0022641	C01	0.7000	30		100	79.49		2.650E+09
MD0065145	C01	0.0500	30		100	5.68		1.893E+08
DE0020230	C09	0.3500	7		2	9.27		2.650E+07
Red Clay Creek								
DE0021709	R05	0.0150	15		100	0.85		5.678E+07
PA0055425	R06	0.0005	20	200		0.04	3.785E+06	0.000E+00
DE0050067	R04	0.0015	30		100	0.17		5.678E+06
DE0000451	R04	2.1700	20		2	164.29		1.643E+08
PA0055107	R03	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0053554	R02	0.0000	100	200	100	0.00	0.000E+00	0.000E+00
PA0024058	R02	1.1000	30	200	100	124.92	8.328E+09	4.164E+09
PA0050679	R01	0.2500	10	2	2	9.46	1.893E+07	1.893E+07
PA0057720-001	R01	0.0720	30	200	100	8.18	5.451E+08	2.725E+08
PA0057720-002	R01	0.0900	10	2	2	3.41	6.814E+06	6.814E+06
White Clay Creek								
DE0000191	W12	0.0300	10		2	1.14		2.271E+06
PA0053783	W01	0.0200	10	200	100	0.76	1.514E+08	7.571E+07
PA0024066	W02	0.2500	30	200	100	28.39	1.893E+09	9.464E+08
PA0052451	W09	0.0012	30	200	100	0.14	9.085E+06	4.542E+06
PA0057029	W08	0.1440	10	2	2	5.45	1.090E+07	1.090E+07
PA0025488	W06	0.3000	30	200	100	34.07	2.271E+09	1.136E+09
PA0056898	W07	0.0650	30	200	100	7.38	4.921E+08	2.461E+08
PA0040436	W06	0.0090	20	200	100	0.68	6.814E+07	3.407E+07
PA0040665	W05	0.0100	20	200	100	0.76	7.571E+07	3.785E+07

2.1.2 Combined Sewer Overflows

Combined sewer systems (CSSs) are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, CSSs transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a waterbody. However, during periods of heavy rainfall or snowmelt (wet weather) the combined storm water and wastewater volume can exceed the capacity of the sewer system or treatment plant. For this reason, CSSs are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other waterbodies. These overflows, referred to as combined sewer overflows (CSOs), contains storm water and untreated human and industrial waste, toxic materials, and debris. CSOs typically discharge for short periods of time at random intervals due to their association with wet weather events.

There are 38 CSO outfalls in the vicinity of the city of Wilmington. Bacteria loads from these CSOs were determined using the flow rates calculated by the XP-SWMM model and event mean concentrations measured during two storm events in 2003.

2.1.3 Storm Water Phase II Communities

Storm water runoff can contribute bacteria and other pollutants to a waterbody. Material can collect on streets, rooftops, parking lots, sidewalks, yards and parks and then during a precipitation event this material can be flushed into gutters, drains and culverts and be discharged into a waterbody.

As part of the 1987 amendments to the CWA, Congress added Section 402(p) to the Act to cover discharges composed entirely of storm water. Section 402(p)(2) of the CWA requires permit coverage for discharges associated with industrial activity and discharges from large and medium municipal separate storm sewer systems (MS4s). Large MS4s serve populations over 250,000 and medium MS4s serve populations between 100,000 and 250,000. These discharges are referred to as Phase I MS4 discharges. EPA issued regulations on December 8, 1999 (64 FR 68722), expanding the NPDES storm water program to include discharges from smaller MS4s, including all systems within urbanized areas and other systems serving populations less than 100,000 as well as storm water discharges from construction sites that disturb one to five acres, with opportunities for area-specific exclusions. This expansion is referred to as Phase II of the MS4 program.

Storm water discharges that are regulated under Phase I and Phase II of the NPDES MS4 program are point sources that must be included in the WLA portion of a TMDL. Storm water discharges not currently subject to Phase I or Phase II of the MS4 program are not required to obtain NPDES permits. Therefore, for regulatory purposes, are analogous to nonpoint sources and are included in the LA portion of a TMDL.

An EPA Memorandum from Robert Wayland and James Hanlon, Water Division Directors, dated November 22, 2002, (see Appendix B) clarified existing regulatory requirements for MS4s connected with TMDLs). The key points are:

- NPDES-regulated MS4 discharges must be included in the WLA component of the TMDL and may not be addressed by the LA component of TMDL.

- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls.

- Industrial storm water permits need to reflect technology-based and water quality-based requirements.

Most of the townships and boroughs within the Christina River Basin in Chester County and all of New Castle County are covered by the Phase II MS4 program regulations. The delineation of the storm water collection system contributing areas within each municipality has not been completed at the present time. Therefore, it is not possible to assign a WLA specific to the storm sewer collection areas within each MS4 municipality. Instead, the TMDL will be presented as a WLA for the entire land area of the township, borough, or county. In the future, when the storm sewer collection systems have been delineated, it is anticipated that the State's storm water program will revise the WLA into the appropriate WLA and LA as part of the storm water permit reissuance. Note that the overall reductions in the TMDL will not change.

Runoff from urban areas may carry significant loads of bacteria and sediment and increased storm runoff flows may cause streambed and bank erosion. To assess the relative loads of bacteria and sediment from different land uses within municipal boundaries, it was important to have an inventory of municipal land use data as a proportion of the HSPF subbasins in which the municipality resides. Since the 1995 land use data available for assessing the municipalities is different than the land use categories used by the USGS to develop their HSPF models of Christina River Basin, an aggregated land use was developed for this purpose as shown in Table 2-3. A list of MS4 municipalities in the study area is provided in Table 2-4 and their locations are shown in Figure 2-2.

Table 2-3. Aggregated land use categories used for MS4 assessments

Aggregated Land Use for MS4 Assessments	HSPF Land Use	1995 Land Use
Residential	Residential-septic Residential-sewer	Single family Multi-family
Agricultural	Agricultural-cows Agricultural-crops Agricultural-mushroom	Agriculture
Open Land	Open land	Public/private open space
Forest	Forest	Wooded
Water	Wetlands, water	Water
Urban	Commercial/industry Undesignated use Roads, building-residential Roads, building-urban	Vacant Transportation/utility Unknown Institutional Industrial Commercial Mining

Table 2-4. Municipalities with MS4 permits in the Christina River Basin

Permit Number	**Municipality Name**	**HSPF Model Subbasins**
PAG130079	Avondale Borough	W04, W06, W07, W08
PAG130047	Birmingham Township	B15, B16
PAG130053	Caln Township	B03, B30, B12
PAG130142	Chadds Ford Township	B16, B17, B18
PAG130066	City of Coatesville	B05
PAG130140	Downingtown Borough	B12, B13, B30
PAI130523	East Bradford Township	B08, B14, B15, B29
PAI130524	East Brandywine Township	B10, B11, B12, B30
PAI130536	East Caln Township	B13, B29
PAI130512	East Fallowfield Township	B05, B06, B20, B23
PAG130123	East Marlborough Township	B07, B22, B31, R01, R03
PAG130058	Franklin Township Chester County	W01, W03, W08, C02
PAI130535	Honey Brook Township	B01, B02, B09
PAG130037	Kennett Square Borough	R01, R03
PAG130146	Kennett Township	B16, B17, R01, R02, R03,R04, R06, W17
PAG130062	London Britain Township	W03, W09, W10, W11, C02

Permit Number	Municipality Name	HSPF Model Subbasins
PAI130503	London Grove Township	W02, W03, W04, W05, W06,W08
PAI130516	New Garden Township	W06, W07, W08, W09, R01, R02
PAI130526	New London Township	W01, W02
PAI130539	Penn Township	W01, W02
PAG130134	Pennsbury Township	B16, B17, B31, R06
PAG130113	Pocopson Township	B07, B08, B15, B31
PAG130101	Sadsbury Township	B20
PAG130163	South Coatesville Borough	B05, B06
PAG130067	Thornbury Township	B15, B16
PAI130527	Upper Uwchlan Township	B10, B11, B27
PAI130505	Uwchlan Township	B11, B12, B27, B29
PAG130150	Valley Township	B03, B04, B05, B33
PAI130529	Wallace Township	B09, B10, B26, B27, B35
PAI130511	West Bradford Township	B06, B07, B08, B13, B14, B24, B25, B30
PAG130100, PAI130544	West Brandywine Township	B02, B03, B10, B30
PAG130145	West Caln Township	B01, B02, B03, B20, B32, B33
PAG130002	West Chester Borough	B14, B15
PAG130144	West Grove Borough	W02, W04
PAI130530	West Whiteland Township	B28, B29
DE0051071	City of Wilmington, DE	B34, C05
DE0051071	Elsmere, DE	C04, C05
DE0051071	Newport, DE	C09
DE0051071	City of Newark, DE	W11, W12, C01, C02, C03
DE0051071	New Castle County, DE	B17, B18, B19, B34, R04, R05, R06, R07, R08, R09, W09, W10, W11, W12, W13, W14, W15, W16, W17, C01, C02, C03, C04, C05, C06, C07, C08, C09

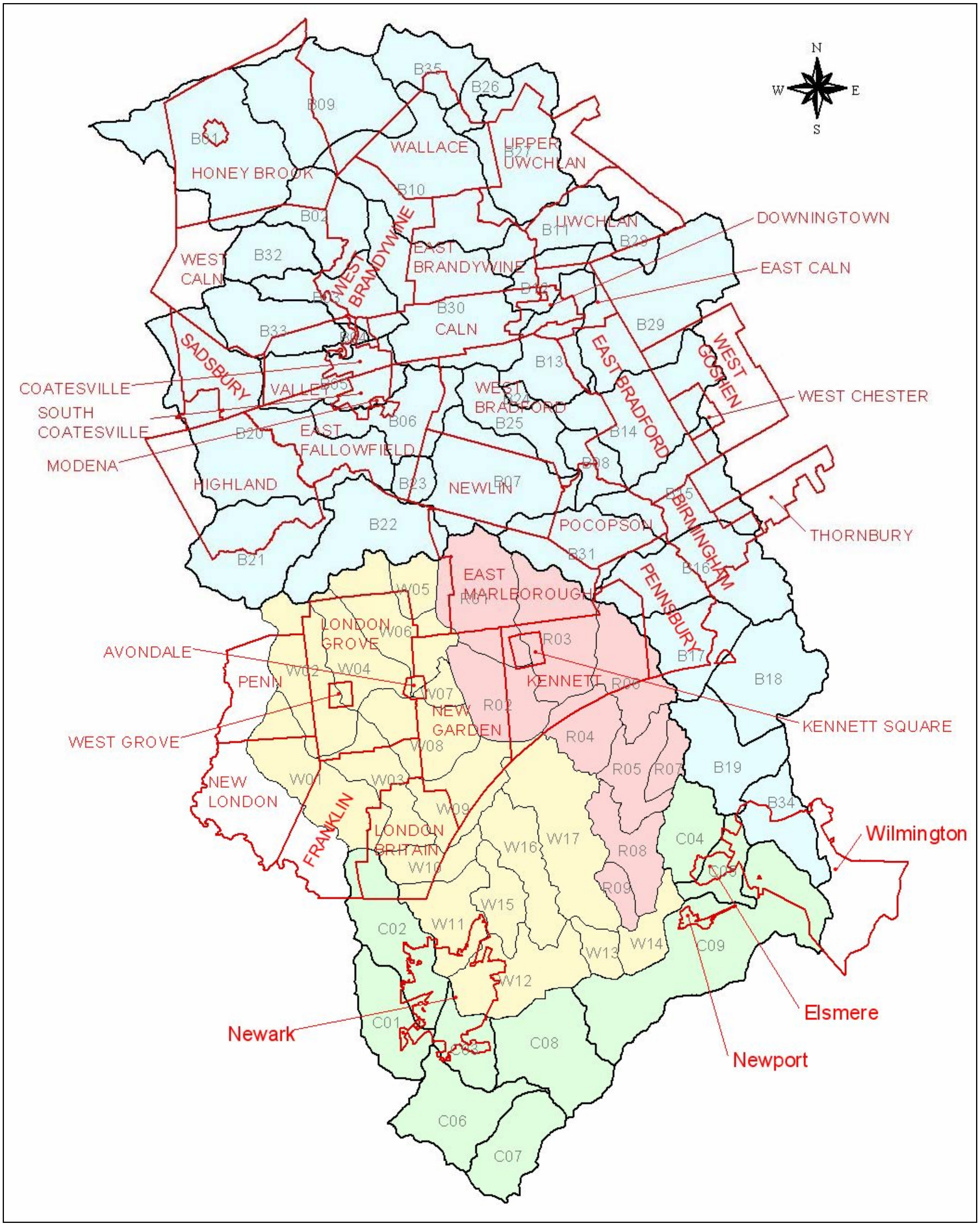

Figure 2-2. Municipalities with MS4 permits in Christina River Basin

2.2 Nonpoint Sources

Nonpoint sources of sediment and bacteria are generally much more difficult to identify and quantify than are point sources. In residential and urban areas, nonpoint sources can include leaking or faulty septic systems, landfill seepage, pet waste, storm water runoff (outside of Phase II communities) and other sources. In more rural areas, major contributors can be pasture runoff, manure storage and spreading, concentrated animal feedlots, and wildlife.

2.2.1 Septic Systems

Septic systems that are properly designed and maintained should not serve as a source of contamination to surface waters. However, septic systems do fail for a variety of reasons. Common soil-type limitations that contribute to septic system failure include seasonal high water table levels, compact glacial till, bedrock, and coarse sand and gravel outwash. When septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters down gradient (Horsely and Witten, 1996).

Site-specific information on the locations or numbers of septic systems in Chester County was not available. A GIS database maintained by DNREC contained information on the number of septic systems in the New Castle County portion of the Christina River Basin for the years 1997 and 2004. This inventory was interpolated and extrapolated to estimate the number of septic systems in 1990, 1995, and 2005 (see Table 2-3). Estimates of the bacteria loads from septic systems will be based on the assumptions outlined below:

- Number of septic systems (based on US Census 1990 and 2000 and DNREC GIS database)
- Estimated population served by the septic systems (an average of 2.8 people per septic system, US Census 1990)
- An average daily discharge of 70 gallons/person/day (Horsley and Witten, 1996)
- Septic effluent fecal coliform concentration of 1.0E+07 cfu/100mL bacteria concentration (Powelson and Mills, 2001) from malfunctioning septic systems
- Septic effluent enterococcus concentration of 8.0E+05 cfu/100mL from malfunctioning septic systems
- Septic effluent concentrations of 200 cfu/100mL (fecal coliform) and 100 cfu/100mL (*enterococci*) from properly functioning septic systems

The number of septic tanks in Chester County was estimated from US Census data (obtained online from http://factfinder.census.gov/). Examination of the number of housing units in rural areas in the two counties reported in the 1990 U.S. Census revealed that approximately each rural housing unit has a septic system (see Table 2-5). Since no septic system information was available from the 2000 US Census data, estimates were made based on information from the Chester County Health Department (CCHD, 2005). In Chester County, approximately 1,500 permits for septic systems are issued every year of which about 600 of are for repair work and 1,100 are for new permits. The total number of septic systems in Chester County in 2005 was estimated as about 69,000 based on the number in 1990 plus 1,100 new systems per year. Since about 80 percent of the septic systems in Chester County are within the Christina River Basin, there were about 55,200 septic systems in the Chester County portion of the basin in 2005.

Table 2-5. Census data related to septic system estimation

Category	New Castle County	Chester County
1990 Census: Number of rural housing units in County	10,335	50,396
1990 Census: Number septic systems in County	12,142	52,493
1990 Census: Rural population in County	29,468	146,612
1990 Estimated number septic systems in Christina River Basin	10,500	42,000
1995 Estimated number septic systems in Christina River Basin	7,041	46,400
1997 DNREC Inventory of septic systems in Christina River Basin	5,455	-
2004 DNREC Inventory of septic systems in Christina River Basin	1,713	-
2005 Estimated number septic systems in Christina River Basin	1,650	55,200
2005 Estimated number of malfunctioning septic systems	17	552
2005 Estimated potential bacteria load (cfu/year)	3.6E+11	1.5E+14

The potential annual bacteria load from malfunctioning as well as properly functioning septic systems was estimated using the data in Table 2-5. According to CCHD (2005), 600 permits are issued for repair work, which is approximately one percent of the total number of septic systems in Chester County. Therefore, it was assumed that at any given time one percent of the septic systems were malfunctioning. The same failure rate was applied to New Castle County.

2.2.2 Agriculture Activities

Land used for agricultural purposes can be a significant source of sediment and bacteria. Runoff from pastures, livestock operations, improper land application of animal wastes, and livestock with access to waterbodies are all potential agricultural sources. Animals grazing in pasturelands deposit manure directly upon the land surface. Even though a pasture may be relatively large, and animal densities low, manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of contaminated runoff during a storm event. The occurrence and degree of bacteria loads from livestock are linked to temporally and spatially variable hydrologic factors, such as precipitation and runoff, except when manure is directly deposited into a waterbody (EPA, 2001).

The application of manure that has been improperly composted can contribute bacteria that are conveyed into surface waters during runoff events. The bacterial content of animal waste varies with collection, storage, and application method. Therefore, animal wastes must be handled, stored, utilized and/or disposed of in an efficient way to minimize waterbody impacts. Grazing animals, confined animal operations and manure application are all potential sources of nutrients and bacteria in the Christina River Basin. The inventories of livestock in Chester County and New Castle County from the last three agricultural census periods are shown in Table 2-6.

The monthly-varying fecal coliform bacteria accumulation rates used in the watershed-loading model categorized by land use in Chester County are provided in Table 2-7. The enterococci bacteria accumulation rates broken down by land use for enterococci bacteria for Chester County and New Castle County are given in Tables 2-8 and 2-9, respectively.

Table 2-6. Livestock inventories from 1992, 1997, and 2002 USDA Agriculture Census

Category	**Chester County, PA**			**New Castle County, DE**		
	1992	1997	2002	1992	1997	2002
Cattle and calves	50,795	48,897	41,878	3,446	2,628	2,665
Hogs and pigs	11,855	2,357	12,860	630	51	86
Poultry (layers, broilers, turkeys)	734,087	599,360	696,361	209,195	220,308	NA
Horses and ponies	4,330	5,293	8,597	770	737	833
Sheep and lambs	3,421	2,154	2,856	238	222	366

NA = not available

Table 2-7. Fecal coliform bacteria accumulation rates (cfu/acre/day) for Chester County

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07
RESIDENTIAL-SEWER	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07
COMMERCIAL/INDUSTRY	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06
AGRICULTURAL-COWS	5.1E+09	5.1E+09	2.0E+10	2.0E+10	2.0E+10	2.0E+10
AGRICULTURAL-CROPS	6.1E+09	6.1E+09	9.5E+09	1.0E+10	1.0E+10	1.0E+10
AGRICULTURAL-MUSHROOM	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
FOREST	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
OPEN LAND	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
WETLANDS, WATER	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
undesignated use	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
ROADS,BUILDING-residential	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
ROADS,BUILDING-urban	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07
RESIDENTIAL-SEWER	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07
COMMERCIAL/INDUSTRY	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06
AGRICULTURAL-COWS	2.0E+10	2.0E+10	2.0E+10	2.0E+10	1.0E+10	5.1E+09
AGRICULTURAL-CROPS	1.0E+10	1.0E+10	1.0E+10	1.0E+10	9.3E+09	6.1E+09
AGRICULTURAL-MUSHROOM	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
FOREST	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
OPEN LAND	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
WETLANDS, WATER	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
undesignated use	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
ROADS,BUILDING-residential	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
ROADS,BUILDING-urban	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07

Table 2-8. ***Enterococci*** **accumulation rates (cfu/acre/day) for Chester County**

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	8.90E+07	8.90E+07	2.50E+08	3.30E+08	3.10E+08	2.90E+08
AGRICULTURAL-CROPS	3.00E+07	3.00E+07	9.00E+07	2.40E+08	2.20E+08	1.20E+08
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+06	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+07	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	2.80E+08	2.80E+08	3.30E+08	2.70E+08	1.90E+08	8.90E+07
AGRICULTURAL-CROPS	1.20E+08	1.20E+08	1.40E+08	4.90E+08	4.60E+08	3.00E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07

Table 2-9. ***Enterococci*** **accumulation rates (cfu/acre/day) for New Castle County**

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	6.10E+08	6.10E+08	2.00E+09	2.00E+09	2.00E+09	2.00E+09
AGRICULTURAL-CROPS	1.20E+07	1.20E+07	2.50E+07	1.30E+08	1.30E+08	3.30E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05

Land Use	JUL	AUG	SEP	OCT	NOV	DEC
AGRICULTURAL-COWS	2.00E+09	2.00E+09	2.00E+09	2.00E+09	1.00E+09	6.10E+08
AGRICULTURAL-CROPS	3.20E+07	3.20E+07	3.60E+07	4.00E+08	4.00E+08	1.20E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07

2.2.3 Wildlife

Wildlife also generates bacteria on the land surfaces and in streams. Wild animals are also assumed to be the only source of bacteria on forested land. A precise estimate of the number of wild animals in the Christina River Basin is not available. Literature and empirical values are used in this study, as shown in Table 2-10, to estimate wild animal population densities for different land use categories. Monthly adjustment factors were used to account for seasonal variations in wild animal populations.

Table 2-10. Estimated wildlife density for associated land uses in Christina River Basin

Wild Animals	Agricutlure-Rowcrop (Animals/sq mile)	Agricutlure-Livestock (Animals/sq mile)	Forest Animals/sq mile)
Ducks	30	30	10
Geese	50	50	0
Deer	0	35	35
Beaver	5	5	10
Raccoons	2.5	2.5	5
Other	320	160	160

2.2.4 Domestic Pets

Domestic pets are potential sources of bacteria in a similar way as wildlife. Cats and dogs can contribute fecal material within the watershed that may find its way into surface waters. This source is more likely in more populated areas where large numbers of pets tend to be found.

A 1999 national study American Pet Products Manufactures Association (APPMA, 1999) reported that 39.1 percent of households own at least one dog and 32.1 percent own at least one cat. The average number of dogs per dog-owning household is 1.41, and the average number for cats is 2.40 per cat-owning household. There are an estimated 149,812 households in the Christina River Basin (US Census Bureau, 2000). Based on the APPMA national study, approximately 58,576 households own dogs and 48,090 households own cats. Using these values results in an estimate of 82,593 dogs and 115,415 cats within the Christina River Basin. The bacteria load from these animals was estimated in the HSPF watershed model runoff from urban and residential areas.